Renewable and Sustainable Energy Reviews 20 (2013) 519–538

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Greener energy: Issues and challenges for Pakistan—wind power prospective

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ARTICLE INFO

Article history:
Received 7 June 2011
Received in revised form
4 December 2012
Accepted 9 December 2012
Available online 12 January 2013

Keywords:
Green energy
Wind energy
Sustainable development
Pakistan

ABSTRACT

Energy is one of the essential inputs for economic development and industrialization. A reliable supply of energy is essential to maintain and to improve human being's living conditions. The management of energy sources, rational utilization of energy, and renewable energy source usages are vital. Among the renewable energy sources wind energy is currently viewed as one of the most significant, fastest growing, and commercially attractive source to generate electrical energy because of the mature and cost effective energy conversation technology. Developing a utility-scale wind project is a complicated and time-consuming process which involves developers, landowners, utilities, the public and various local authorities. This article discusses the past, the present and the future of wind energy use in Pakistan. The efforts for the utilization of wind energy in the country are presented as well, along with barriers in its development. It is concluded that the potential exists, but significant efforts are needed to effectively make use of this cheap renewable energy source.

Contents

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http://dx.doi.org/10.1016/j.rser.2012.12.010

1. Introduction and background

Rising concern about the effect of greenhouse gas (GHG) emissions on climate change is pushing national governments and the international community to achieve sustainable development in an economy that is less dependent on carbon emitting activities (the vision that is usually termed a ''low-carbon society'' (LCS)). Since the utilization of energy resources is the main source of GHG emissions, restructuring current energy systems in order to incorporate low-carbon energy technologies is essential for the realization of the LCS vision. Energy policies promoting the penetration of these technologies must view the role of energy in society as a system composed of several energy resources, conversion technologies and energy demand sectors [1].

To address these concerns to some extent, global communities are trying to find and implement different energy saving strategies, technology, and alternative sources of energy for different sectors that rely on energy produced from different sources. In that regard development of wind energy is anticipated to play a significant role to meet future energy demand which can reduce environmental pollution to a certain extent [2]. Wind turbines, both large and small, produce electricity for utilities and home owners and remote villages. When wind turbines are grouped together, they are referred to as ''wind farms''. Wind farms comprise the turbines themselves, plus roads for site access, buildings (if any) and the grid connection point. In fact over the last ten years wind energy is the world's fastest growing energy source with an average annual growth rate of 31.1% [3]. It is predicted that wind energy will provide 5% of the world's energy in 2020 [4].

Windmills have been used for at least 3000 years, mainly for grinding grain or pumping water; while in sailing ships the wind has been an essential source of power. In fact, the word mill is derived from the Latin word for a machine used for grinding grain. From medieval times, horizontal axis windmills were an integral part of the rural economy and only fell into disuse with the advent of cheap fossil-fuelled stationary engines and then the spread of rural electrification [5,6].

In the beginning, the primary motivation for basically all the research in wind-power was to strengthen the mechanization of agriculture through local-made electricity. With the electrification of the industrialized world, however, the role of wind-power decreased. It was not able to compete with the fossil-burning power stations, which showed to be far more competitive in providing electrical power on a large scale. Lack of fossil fuels during World War I and later World War II created an awareness of the great dependence on fossil fuels and gave wind-power renewed attention. The prices for wind-powered electricity were still not competitive and politically nuclear power was given more attention and hence more research funds.

It was the oil crises in the 1970s creating the supply-problems and price fluctuations on fossil fuels when wind-power once again was put on the agenda. In many countries in the 1970s a new era for wind power started and spurred the development of a global industry which today is characterized by relatively few but very large wind-turbine manufacturers -primarily from Denmark, Germany, Spain, China, India and the US.

During 1973–1986, the commercial wind turbine market evolved from domestic and agricultural applications of small machines in the 1 kW to 25 kW size range to utility interconnected wind farm applications of intermediate-scale machines of 50 kW to 600 kW [7,8]. However medium to large grid-connected wind turbine generators are particularly becoming the most important and fastest growing form of electricity generation. They attract interest as one of the most cost-effective ways to generate electricity from renewable energy resources [9]. Indeed, this renewable energy ranks second after hydroelectric in terms of installed capacity and rapid growth [10]. New markets are emerging and existing markets are expanding. Jacobson and Delucchi [11] ranked several long-term energy systems with respect to their impacts on global warming, air pollution, water supply, land use, wildlife, thermal pollution, water–chemical pollution and nuclear weapons proliferation. The ranking of electricity options, starting with the highest, included: wind power, concentrated solar, geothermal, tidal, solar photovoltaic, wave, and hydroelectric power, all of which are powered by wind, water, or sunlight (WWS). The study also found that battery-electric vehicles and hydrogen fuel-cell vehicles recharged by WWS options would largely eliminate pollution from the transportation sector. Jacobson and Delucchi [11] also concluded that coal with carbon capture, corn ethanol, cellulosic ethanol, and nuclear power were all moderately or significantly worse than WWS options with respect to environmental and land use impacts. Jacobson and Delucchi [12] outlined a large-scale plan to power the world for all purposes with WWS (no biofuels, nuclear power, or coal with carbon capture). The study found that it was technically feasible to power the world with WWS by 2030 but such a conversion would almost certainly take longer due to the difficulty in implementing all necessary policies. Same study also suggests converting to a WWS energy infrastructure will reduce 2030 world power demand by 30%, primarily due to the efficiency of electricity compared with internal combustion. The amount of wind power plussolar power available in likely developable locations over land outside of Antarctica exceeds projected world power demand by more than an order of magnitude. Jacobson and Delucchi [13] concluded that barriers to a 100% conversion to WWS power worldwide are primarily social and political, not technological or even economical.

Globally, 1700 TW (Trillion Watts) of wind energy are available over the world's land plus ocean surfaces at 100 m if all wind at all speeds were used to power wind turbines however, the wind power over land is around 72–170 TW in locations over land and near shore where the wind speed is 7 m/s or faster (the speed necessary for cost-competitive wind energy) [14,15]. Over half of this power is in locations that could practically be developed. This vast potential can be exploited to produce electricity on both community and wind farm scales. Applications other than electricity production, such as water pumping, also have vast applications. The maturity of wind energy is high because it has been used since olden times in many economic activities [16].

Wind-generated electricity contributed over 1% of global demand for the first time in 2007, when installed capacity grew to 94 GW [17]. The worldwide wind capacity reached 254 GW by the end of June 2012. European Union has set a binding target of a 20% renewable energy contribution by 2020, which equates to 34% of electricity production. It is estimated that wind energy could contribute one-third of this production [18]. In American Chemical Society's 240th National Meeting Walter Kohn, who shared the 1998 Nobel Prize in Chemistry noted that continuous research and development of alternative energy could soon lead to a new era in human history in which two renewable sources, solar and wind, will become Earth's dominant contributor of energy [19]. According to findings from the International Scientific Congress "Climate Change: Global Risks, Challenges & Decisions." Renewable energy is essential to modern society—reducing harmful emissions from fossil fuels and making us more self-sufficient. Most of the technologies needed to shift the world from fossil fuel to cleanrenewable energy. Implementing that technology requires overcoming obstacles in planning and politics. With adequate financial and political support, renewable energy technologies like wind and photovoltaic could supply 40% of the world's electricity by

2050, However, if such technologies are marginalized, its share is likely to hover below 15% [20].

2. Definitions, terminologies and evaluation criteria

In the evaluating wind energy conversion systems (WECS), many different terms, criteria and parameters are used. Voorspools and D'haeseleer [21] has critically evaluated these terms and parameters:

The *rated power* of WECS is the installed capacity. It is the maximum power that can be generated under ideal wind conditions. The *capacity factor or load factor* is the actual electric energy generation as a fraction of the electricity that could be generated at rated power over the same period of time. The load factor is often expressed in *equivalent full-load hours* representing the time the WECS would have to operate annually at rated power to reach the annual generation, e.g., a capacity factor of 30% corresponds to an equivalent full-load use of 2628 h/year. In the reliability evaluation of power systems, stochastic reliability indices can be used. A first category, designated as the *loss-of-load* or LOL group, is capacity-based. The *LOLP* (*P stands for probability*) gives the probability that electricity demand, or the 'load' exceeds the available generating capacity at a given time. The *LOLE* (*E stands for expectation or expectancy*) is the expected period during which the system load is expected to exceed the available generating capacity. The LOLE is most often expressed in hours per year but can also be presented as a percentage or probability by dividing through a full year (8760 h).

A second group of reliability indices includes information on the depth of the power failure. The *EUE, or expected no served energy*, is the total amount of energy expected not to be supplied by the system. The EUE is sometimes referred to as the *LOEE, loss of energy expectation or EENS*, expected energy not supplied. The capacity credit of a WECS is the fraction of its rated power that can be considered 'equally reliable' as its conventional alternative. More precisely, the capacity credit expresses how much conventional dispatchable power can be avoided or replaced by the WECS without changing the system reliability. So, 1000 MW of wind turbines with a capacity credit of 30% can avoid a 300 MW investment in conventional power. The *effective load-carrying capability or ELCC* stands for the additional load that can be carried by a system including WECS (compared to that same system without the WECS) without changing the overall power-generation reliability. The ELCC and the capacity credit should lead to comparable results. The capacity credit is obtained by looking at the savings possible in the supply side where the ELCC is calculated by altering the system load.

Energy ratio (E_R), as defined here, is the ratio of gross energy output from the device over its operating life divided by the total lifetime energy inputs, with both input and output energy given in primary energy terms. More elaborated explanation for other related terms can be found in Ref. [22–24]. In the assessment of wind power, the best results are obtained by using the full set of chronological data for the WECS, load and wind variability taken over several years [21].

3. Characteristics of wind technology

Wind has considerable amount of kinetic energy when blowing at high speeds. This kinetic energy when passing through the blades of the wind turbines is converted into mechanical energy and rotates the wind blades and the connected generator, thereby producing electricity. Wind turbines operate on a simple principle. The energy in the wind turns two or three propeller-like blades around a rotor. The rotor is connected to the main shaft, which spins a generator to create electricity. Generally, a gearbox turns the slow-moving turbine rotor into faster-rotating gears, which converts mechanical energy to electricity in a generator. Some modern turbines are gearless. Although less efficient, small turbines can be used in homes or buildings.

4. Characteristics of wind power technology

The development of contemporary wind turbine in the course of time may be reflected by the gradual upscale of machine. Wind farms today appear on land and offshore, with individual turbines ranging in size up to 7 MW. Designs of machines that will exceed the nominal power of 10 MW are already underway [12,25]. Modern turbines are modular and quick to install, whilst wind farms vary in size from a few MW to several hundred MW [26]. Wind turbines will typically start generating electricity at a wind speed of 3 m/s to 5 m/s, reach maximum power at 15 m/s and generally cut-out at a wind speed of around 25 m/s [27]. The primary materials needed for wind turbines include steel (for towers, nacelles, rotors, etc.), pre-stressed concrete (for towers), magnetic materials (for gearboxes), aluminum (nacelles), copper (nacelles), wood epoxy (rotor blades), glassfiber reinforced plastic (for rotor blades), and carbon-filament reinforced plastic (for rotor blades) [12].

5. Modern wind turbines

A wind turbine primarily consists of a turbine tower, which carries the nacelle, and the turbine rotor, consisting of rotor blades and hub [28]. Most modern wind turbines have three rotor blades usually placed upwind of the tower and the nacelle. On the outside the nacelle is usually equipped with anemometers and a wind wane to measure the wind speed and direction, as well as with aviation lights. The nacelle contains the key components of the wind turbine, e.g. the gearbox, mechanical brakes, electrical generator, control systems [29]. Under normal operating conditions the nacelle would be facing the upstream wind direction [30]. Generally, three blades made up of Fiber Reinforced Polyester are mounted on the hub, while in the nacelle the major parts are housed. The hub connects the gearbox and the blades. Solid high carbon steel bars or cylinders are used as main shaft. The gearbox is used to increase the speed ratio so that the rotor speed is increased to the rated generator speed [31] (it is the most critical component and needs regular maintenance). Oil cooling is employed to control the heating of the gearbox. Gearboxes are mounted over dampers to minimize vibration. Failure of gearbox may put the plant out of operation for an entire season as spares are often not available. The main components of a modern wind turbine system are illustrated in Fig. 1, including the turbine rotor, gear box, generator, transformer and possible power electronics.

Wind power technologies come in a variety of sizes and styles and can generally be categorised by whether they are horizontal axis or vertical axis wind turbines (HAWT and VAWT), and by whether they are located onshore or offshore. These wind turbines account for almost all utility scale wind turbines installed. Vertical-axis wind turbines are theoretically less aerodynamically efficient than horizontal-axis turbines and do not have significant market share. In addition to large-scale designs, there has been renewed interest in small-scale wind turbines, with some innovative design options developed for local community. Small wind turbines are generally considered to be those with generation capacities of less than 100 kW.

Horizontal axis turbines resemble airplane propellers, with two to three rotor blades fixed at the front of the tower and facing

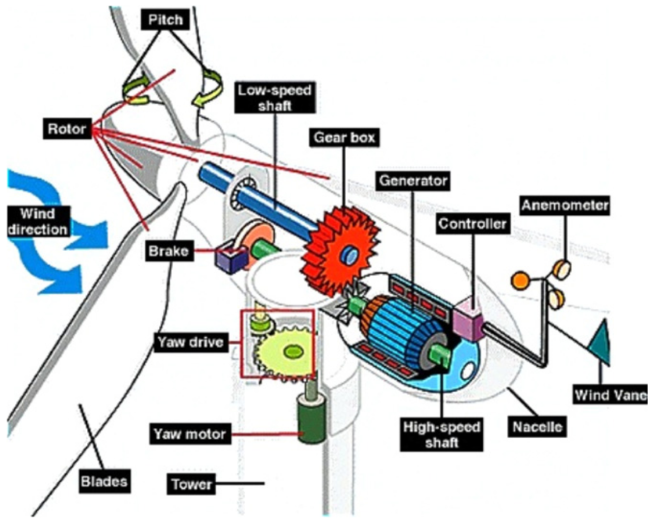

Fig. 1. Schematic diagram of a modern horizontal-axis, three-bladed wind turbine [29].

into the wind. This is the most common design found today, making up most of the large utility-scale turbines on the global market. Vertical axis turbines resemble a large eggbeater with rotor blades attached vertically at the top and near the bottom of the tower and bulging out in the middle. Wind turbines have a design lifetime of 20–25 years, with their operation and maintenance costs typically about 3–5% of the cost of the turbine [32].

The conversion of wind power to mechanical power is done aerodynamically. The available power depends on the wind speed but it is important to be able to control and limit the power at higher wind speed to avoid damage. The power limitation may be done by stall control (the blade position is fixed but stall of the wind appears along the blade at higher wind speed), or active stall (the blade angle is adjusted in order to create stall along the blades) or pitch control (the blades are turned out of the wind at higher wind speed), which result in power curves [29].

In the search for wind power, the most important decisions are concerned with exploitation of local, clean and sustainable energy resources. The determination of wind energy potential depends very much on the meteorological measurements of the wind direction, velocity and solar irradiation. The physical behavior of wind shows great temporal and spatial variability [33]. In meteorology, wind is defined as air in motion because of uneven heating and cooling of the earth surface. The horizontal movement of air parallel to the earth surface is a measure of the wind in both direction and magnitude, which change most frequently. As a result, wind prediction is very difficult due to random change both in wind direction and speed. This changeability adds another measure importance to wind power. Although good wind potential areas are now harder to find, exploitation of wind energy per kW has increased due to improved efficiency of contemporary turbines, sophisticated assessment of the local wind potential, considerable reduction of downtime periods, upgrade of networks and operation of offshore applications [25].

The suitable voltage level is related to the amount of power generated. A modern wind turbine is often equipped with a transformer stepping up from the generator terminal voltage, usually a voltage below 1 kV, to a medium voltage around 20 kV or 30 kV, for the local electrical connection within a wind farm. If the wind farm is large and the distance to the grid is long, a transformer may be used to further step up the medium voltage in the wind farm to a high voltage at transmission level. For example, for large onshore wind farms at hundreds of MW level, high voltage overhead lines above 100 kV are normally used. For offshore wind farms with a long distance transmission to an onshore grid, a high voltage submarine cable with a lead sheath and steel amour may have to be used. The power generated by an offshore wind farm is transferred by the submarine cables buried in the sea bed. The cables between the turbines are linked to a transformer substation, which, at most cases, will be placed offshore due to the long distance to shore. For near shore wind farms (5 km or less from the shore) it may be placed onshore. Either oil-insulated cables or cross-linked polyethylene insulated cables can be used. The reactive power produced by the submarine cable connecting an offshore wind farm could be high, a 40 km long cable at 150 kV would produce around 100 Mega volt ampere reactive (Mvar), reactors may be needed to compensate the reactive power produced by the cable [29,34]. For long distance transmission, the transmission capacity of the cables may be mainly occupied by the produced reactive power. In this situation high voltage direct current (HVDC) transmission techniques may be used. The new technology, voltage source converter based HVDC system, provides new possibilities for performing voltage regulation and improving dynamic stability of the wind farm as it is possible to control the reactive power of the wind farm and perhaps keep the voltage during a fault in the connected transmission systems [29].

Integration of large scale wind power may have severe impacts on the power system operation. Stable, reliable and economic operation of the power system under the massive integration of wind power is a big challenge to power system operators. The technical specifications, grid codes, for grid connection of wind turbines (the large offshore wind farms to the high-voltage transmission networks as well as the local wind turbines to the distribution networks) have been produced to specify the requirements that wind turbines must meet in order to be connected to the grid. Examples on such requirements include capabilities of contributing to frequency and voltage regulation by continuously controlling the active power and reactive power supplied to the power system, and the low voltage ride-through capability [29].

6. Production cost of wind energy

The production cost at a given location depends predominantly upon the wind speed and to a lesser extent the type, size and configuration of the turbines. The two main barriers to large-scale implementation of wind power are: (1) the perceived intermittency of winds, and (2) the difficulty in identifying good wind locations, especially in developing countries [14].

Wind power generation depends on wind speed. Wind speed could be easily influenced by obstacle and terrain. It also varies with height, so the random character of wind is significant. The reliability of wind power is not satisfactory because it cannot supply steady electricity to power system. So when the wind power penetration (i.e., proportion of wind power in a power system) grows, the power system operation will be affected. As a result, the power system regulators must make detailed schedule plans and set reserve capacity for it. To reduce the reserve capacity and increase the wind power penetration, the accurate forecasting of wind speed is needed.

The wind turbine generators in a wind farm will not have a fixed capacity distribution, owing to the constant variations in the outputs of each wind turbine output despite all of them being fed from the same wind energy source. Hence, a wind energy conversion system cannot produce power at its rated capacity throughout the year. Due to the partial availability of wind generated power, the actual capacity value of a wind power plant in a utility system is relatively low, which is equivalent to the wind power plant's capacity factor multiplied by its rated capacity [35]. The relationship between the wind turbine power output and wind speed is non-linear and hence the power output characteristics of wind energy conversion system are different from that of any conventional generation systems. Even though

wind energy is not consistent, wind power plants contribute to meet the energy demand requirements [36].

The wind power penetration would result in variations of load flows in the interconnected systems, as well as re-dispatch of conventional power plants, which may causes the reduced reserve power capacity. Some actions become necessary to accommodate large scale wind power penetration. For example, the electric grid may need an expansion for bulk electricity transmission from offshore wind farms to load centers, and it may require reinforcement of existing power lines or construction of new power lines, installation of Flexible AC Transmission system (FACTs) devices [37].

7. Dealing with wind farms variable power output

Power output from an individual wind turbine or wind farm varies over time, depending on the weather conditions. The fact that wind output varies is not itself problem, provided that good information is available in advance to predict how much power wind farms will be producing at any given time. Predictability, by means of accurate forecasting, is an essential tool to the successful integration of wind power into the electric power system. Extensive evaluation and modeling is needed before a wind farm is built. The calculations provide information about electricity amount which wind plants will deliver on a seasonal or monthly basis [38].

Transmission system operators – who have little control over demand – have the remarkable task of matching supply to meet whatever demand might be at any moment of the day, or night, during winter and summer alike. With wind power, which is produced by hundreds or thousands of individual wind turbines rather than a few large power stations, such sudden drops should never occur and significant variations should be forecasted and planned. This makes it easier for system operators to predict and manage the changes in supply [38].

In addition, large, interconnected grids lessen the overall impact if the wind stops blowing in one particular place. The idea of new electric 'superhighways', such as the 'supergrid' proposed to tap into the vast offshore wind resource in northern Europe and link these countries' electricity grids with the entire continent, would dramatically help to smooth out the variable output of the individual wind turbines [38].

Earlier generations of wind turbines were unable to respond if there was a fault on the network, and could even aggravate the situation. Today, however, modern wind turbines contribute substantially to the stability of the grid. The majority of turbines being installed today are capable of meeting the most severe grid code requirements, with advanced features including fault-ride-through capability. This enables them to assist in keeping the power system stable when disruptions occur. Modern wind farms are wind energy power plants that can be actively controlled and provide grid support services [38].

8. Common grid code requirements

Increased penetration of wind power into the electricity grid gives rise to new challenges for the entire system and, in particular, to the transmission system operators in maintaining reliability and stability of electricity supply. Although available wind forecasting techniques are suitable and accurate up to some extent but these techniques are not satisfactory especially in the competitive electricity markets. Grid codes are set up to specify the relevant requirements for efficient and secure operation of power system for all network users and these specifications have to be met in order to integrate wind turbines into the grid. Singh and Singh [39] has addressed some technical and operational issues of high penetration of wind power and suggested common grid code requirements.

9. Global investment in wind power programs

Global new investment in sustainable energy reached $162 billion in the year 2009. Wind was even more dominant as a destination for investment in 2009 than in the previous year. In 2008, it accounted for $59 billion or 45% of all financial investment in sustainable energy, but in 2009, its share rose to 56%. Total financial investment in wind last year was $67 billion, compared with $119 billion for all renewable energy technologies [40]. In uncertain economic and financial circumstances, wind was seen as a relatively mature and therefore lower risk, subsector of clean energy.

Several countries now meet a significant share of their electricity demand with wind, including Denmark (20%); Spain (14%), where wind overtook coal for the first time in 2009; and Germany (6%).ii The wind sector on its own accounted for 39% of new power generation in both the EU and the US, making it the largest newly added source of capacity in both regions [40].

Capital costs per kilowatt of installed capacity are taken as an average of €1350 per kW in 2009. Given the high up-front costs of wind power projects, large investments of predominantly private but also public funds are expected to flow into the growing wind power markets. This investment will directly benefit regional development by creating jobs in manufacturing, transportation, construction, project development and operation and maintenance. It will provide new revenue sources to local landowners such as a farmers or communities; and increasing the local tax base. List of ten top wind turbine manufacturers globally in 2010 is given in Table 1·[41]. The list includes three Chinese firms, Sinovel (second), Goldwind (fourth) and Dongfang (sixth). Complete list is given in Table 1. With the exception of GE Wind (US) and Suzlon (India), European and Chinese firms dominate the turbine manufacturing sector.

10. The generation cost of wind energy

Wind energy is a capital-intensive technology, so most of the outgoings will be made at time of investment. The capital cost can be as much as 80% of the total cost of the project over its entire lifetime, with variations between models, markets and locations. The wind turbine constitutes the single largest cost component, followed by grid connection [42]. The key parameters that govern wind power costs are [42]:

- Capital costs, including wind turbines, foundations, road construction and grid connection.

Table 1
The top 10 wind turbine manufacturers globally in 2009.

Manufacture	Country	Annual market share in 2009 (%)
Vestas	Denmark	12.5
GE wind energy	United States	12.4
Sinovel	Peoples Republic of China	9.2
Enercon	Germany	8.5
Goldwind	Peoples Republic of China	7.2
Gamesa	Spain	6.7
Dongfang electric	Peoples Republic of China	6.5
Suzlon	India	6.4
Siemens wind power	Denmark, Germany	5.9
Repower	Germany	3.4

- Variable costs, the most significant being the operation and maintenance (O&M) of wind turbines, but also including other categories such as land rental, insurance and taxes or management and administration. Variable costs are relatively low and will oscillate around a level of 20% of the total investment.
- The electricity produced, which in turn depends on the local wind climate, wind turbine technical specifications, site characteristics and power generation reductions. The indicator that best characterizes the electricity-generating capacity of a wind farm is the capacity factor, which expresses the percentage of time that a wind energy farm produces electricity during a representative year.

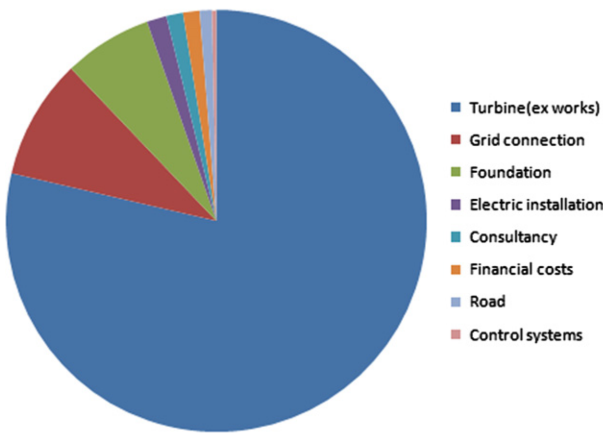

Fig. 2. Cost structure of a typical 2 MW wind turbine installed in Europe in 2006. The average turbine installed in Europe has a total investment cost of around €1.23 million/MW.

- The discount rate and economic lifetime of the investment. These reflect the perceived risk of the project, the regulatory and investment climate in each country and the profitability of alternative investments.

Approximately 75% of the total cost of energy for a wind turbine is related to upfront costs such as the cost of the turbine, foundation, electrical equipment, and grid-connection [43]. Analysis of different markets suggests that there is quite a wide variation in wind turbine prices, depending on the cost structure of the local market. China appears to have the lowest prices, with a turbine price of just $644/kW in 2010 [44]. The wind turbine prices quoted for transactions in 2011 in developed countries are in the range of $ 1100 to $1400/kW [27]. Operation and maintenance make up another 10% of the expenditure, although there is substantial uncertainty around this category due to the fact that few wind turbines have reached the end of their lifetime [42]. A developer needs to have most of the funds available (around 80%) at the time the wind farm is built, so capital access and good repayment conditions become essential. Some projects may not come to fruition due to the finance needed during this initial stage, even though, over time, this may be a cheapest option.

The capital costs of wind projects can be divided into several categories (Fig. 2) [42]:

- The cost of the turbine itself, which comprises the production, blades, transformer, transportation to the site and installation;
- The cost of grid connection, including cables, sub-station, connection and power evacuation systems (when they are specifically related to and purpose-built for the wind farm)
- the cost of the civil work, including the foundations, road construction and buildings;

Table 2
Share of main components of a wind turbine to the overall cost in the 5 MW RE power machine [40].

Components of a wind turbine	Share to the overall cost (%)	Observation/comments
Tower	26.3	Range in height from 40 metes up to more than 100 m. Usually manufactured in sections from rolled steel; a lattice structure or concrete are cheaper options.Towers are made from tubular steel (shown here), concrete, or steel lattice. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity.
Rotor blades	22.2	Most turbines have either two or three blades. Wind blowing over the blades causes the blades to "lift" and rotate. Varying in length up to more than 60 m, blades are manufactured in specially designed moulds from composite materials, usually a combination of glass fibre and epoxy resin. Options include polyester instead of epoxy and the addition of carbon fibre to add strength and stiffness.
Gearbox	12.91	Gears connect the low-speed shaft to the high-speed shaft and increase the rotational speeds from about 30 to 60 rotations per minute (rpm) to about 1000 rpm to 1800 rpm, the rotational speed required by most generators to produce electricity. The gear box is a costly (and heavy) part of the wind turbine and engineers are exploring "direct-drive" generators that operate at lower rotational speeds and do not need gear boxes.Gears increase the low rotational speed of the rotor shaft in several stages to the high speed needed to drive the generator
Generator	3.44	Converts mechanical energy into electrical energy. Both synchronous and asynchronous generators are used. Usually an off-the-shelf induction generator that produces 60-cycle AC electricity.
Power converter	5.01	Converts direct current from the generator into alternating current to be exported to the grid network.
Transformer	3.59	Converts the electricity from the turbine to higher voltage required by the grid.
Main frame	2.80	Made from steel, must be strong enough to support the entire turbine drive train, but not too heavy.
Pitch system	2.66	Adjusts the angle of the blades to make best use of the prevailing wind. Blades are turned, or pitched, out of the wind to control the rotor speed and keep the rotor from turning in winds that are too high or too low to produce electricity.
Main shaft	1.91	Transfers the rotational force of the rotor to the gearbox.
Rotor hub	1.37	Made from cast iron, the hub holds the blades in position as they turn.
Brake system	1.32	A disc brake, which can be applied mechanically, electrically, or hydraulically to stop the rotor in emergencies. Disc brakes bring the turbine to a halt when required.
Nacelle housing	1.35	A shell or cabin made of a polymer-fiberglass composite that holds the turbine equipment at the top of the wind power pole and contains the gear box, low- and high-speed shafts, generator, controller, and brake.
Yaw system	1.25	Mechanism that rotates the nacelle to face the changing wind direction. Upwind turbines face into the wind; the yaw drive is used to keep the rotor facing into the wind as the wind direction changes. Downwind turbines do not require a yaw drive, the wind blows the rotor downwind.
Rotor bearings	1.22	Some of the many different bearings in a turbine, these have to withstand the varying forces and loads generated by the wind.
Screws	1.04	Hold the main components in place, must be designed for extreme loads.
Cables	0.96	Link individual turbines in a wind farm to an electricity sub-station.

- Other capital costs, including development and engineering costs, licensing procedures, consultancy and permits, SCADA (Supervisory, Control and Data Acquisition) and monitoring systems.

The results of survey by Blanco [42] shows that the capital costs of a wind energy project are in the range of 1100–1400 €/kW for newly-established projects in Europe. The generation cost per kW h of an onshore wind farm today ranges between 4.5 and 8.7 €/kW h. As the wind resource is the factor that has a largest influence over the economics of wind energy. For instance, a wind farm with a capital cost of €1100 will be subject to an increase in generation costs of over 50% if the number of full hours decreases from 3000 to 1700 h. This variation remains fairly stable regardless of the level of capital costs. If the lifetime of the investment is of only 16 years, and with a capital cost of €1100, the global cost will rise over 10% [42].

These costs are sensibly lower in some emerging markets, notably China and in the United States of America. There are also variations within the European Union. The reasons behind that spread of values lie on the impact of lower labor costs in some developing countries with manufacturing capacity, the degree of competition in a specific market, the bargaining power of market actors, the national regulation concerning the characteristics of the wind turbine (e.g. the existence of strict grid codes in some regions), the distance and modality of grid connection (including the possibility of having to finance all the cost of a grid upgrade) and the extent of the civil works (which in turn depend on factors such as the accessibility and geotechnical conditions of the site). Wind energy is a capital-intensive technology, with the fixed assets (wind turbine, grid connection and civil works) accounting for as much as 80% of the total cost. Maintenance make up another 10% of the expenditure, although there is substantial uncertainty around this category due to the fact that few wind turbines have reached the end of their lifetime, thus limiting the accuracy of any analysis. The onshore wind energy generation cost is between 4.5 and 8.7 cents/kW h, with the capacity factor and wind turbine cost being the most influential factors. Share of main components of a wind turbine to the overall cost in the 5 MW REpower machine is depicted in Table 2 [45].

The generation costs of wind energy have increased by 20% in the past 3 years, driven by a combination of rising prices of key raw materials and an unexpected surge in the demand for wind turbines, following the approval of favorable support policies in large markets like the US, China and a second round of European Member States. The evolution of steel, cast iron, copper and carbon fiber prices will likely remain, on the rise, since the demand for these materials from other economic sectors and geographical areas is not showing signs of exhaustion [42]. Areas of potential wind turbine improvements include:

- Advanced tower designs, including taller towers, new materials, and telescoping towers that are easier to install.
- Larger rotors made from lighter materials and having improved aerodynamics.
- More efficient gear boxes, drive trains, generators, and electronics.

11. Levelised cost of electricity generation (LCOE)

Following formula is used for calculating the LCOE through renewable energy technologies [27]

$$LCOE = \frac{\sum_{t=1}^{n} I_t + M_t + F_t}{(1+r)^t} \quad (1)$$

where:

- LCOE = the average lifetime levelised cost of electricity generation;
- I_t=investment expenditures in the year t;
- M_t=operations and maintenance expenditures in the year t;
- F_t=fuel expenditures in the year t;
- E_t=electricity generation in the year t;
- r=discount rate; and
- n=economic life of the system.

The LCOE of renewable energy technologies is a widely used measure by which renewable energy technologies can be evaluated for modelling or policy development. LCOE of renewable energy technologies varies by technology, country and project, based on the renewable energy resource, capital and operating costs, and the efficiency and performance of the technology. The LCOE generated from wind is now below $ 0.068/kW h (€0.050/kW h) for most of the projects in high resource areas (United States, Brazil, Sweden, Mexico). This compares to current estimated average costs of $ 0.067/kW h for coal-fired power and $ 0.056/kW h for gas-fired power.

12. Regional development in wind energy

China became the largest wind power market measured by annual installations in 2009, and the largest cumulative installer of wind power capacity in the world in 2010. By 2010, total installed capacity exceeded 40,000 MW, and by 2020, it is estimated that about 200,000 MW of wind power capacity will need to be installed in order to meet China's target for non-fossil energy consumption [46].

The wind turbine market in China has experienced exponential growth in the past few decades, and became the global market leader [47]. By the end of 2009, there were 70 Wind Turbine Manufacturers in the Chinese wind turbine market including 29 state-owned and state-holding enterprises, 23 private enterprises, 10 foreign-owned enterprises and 8 joint ventures [48]. By 2010, the three Chinese enterprises Sinovel, Goldwind and Dongfang were ranked among the top 10 wind power technology manufacturers worldwide. Prior to 2008, most Chinese firms interested in developing wind power technology acquired wind turbine designs through licensing arrangements with foreign firms. More recently Chinese firms have improved in their ability to conduct independent innovation and R&D, both in developing new designs and in assimilating and building upon licensed foreign designs [46]. In addition, many leading global wind turbine manufacturers, including Vestas, Gamesa, GE, and Suzlon, have established production facilities in China. Chinese companies such as Dongfang and Goldwind have gradually mastered the MW-level wind turbine technology, and the installed capacity of the mainstream product in the market has gradually increased, from 600 kW to 1 MW and above. In 2009, manufacturers like Sinovel and Mingyang further mastered 3 MW wind turbine technology, and the market share of MW-level products among the newly installed capacity reached 86.8% in China. In 2010, Sinovel began to produce 5 MW wind power turbines [47]. Lewis [49] argues that technology procurement, adaptation, and commercialization are the main innovation modes of China's wind power industry. The product development methods of Chinese enterprises has gradually shifted from technology transfer to joint design and indigenous research, so commissioned design, joint design, and indigenous design have become the primary means whereby the Chinese brands obtain technology [47,50].

The development of wind power in China has been driven by government policy that simultaneously promoted the deployment of wind power technology and the advancement of a domestic wind power technology industry. In 2003, the China National Development and Reform Commission commenced

awarding concessions to wind power projects that utilized Chinese technology that directly supported the mass production of wind power equipment [48]. This wind power concession provided the local Chinese industry with an early boost. The Renewable Energy Law and its supporting measures established a supportive policy framework for renewable energy development which encompassed target setting, preferential pricing, power purchase mandates, and cost sharing arrangements [46]. Wang and co-workers [46] has identified the shortage of human resources in the wind power industry a long-term threat to sustainability of the industry.

In last two decades Indian wind energy generation has achieved a tremendous growth from 41.3 MW in 1992 to 13,065 MW at the end of 2010 [51]. The Centre for Wind Energy Technology (C-WET) published the Indian Wind Atlas in 2010, which shows large areas with annual average wind power densities of more than 200 W/m^2 at 50 m above ground level. Several Indian home grown wind turbine manufacturing companies make it much easier to expand wind harnessing technology and to produce skilled manpower [51]. M/s. Suzlon is the top wind turbine manufacturer.

Turkey has 796.5 MW installed wind energy capacity at the end of 2009 [52]. In 2010, 528 MW of new wind energy capacity was added [53]. A number of policy measures have helped to increase renewable production in Turkey in recent years. These include the obligation of the national transmission company to provide grid connection to all renewable power projects. In Turkey wind power producers are free to sell to the national power pool or engage directly with eligible customers in bilateral agreements where prices are much higher than the guaranteed price [54]. The renewable generators can install generation facilities with an installed capacity lower than 500 kW without obtaining a license or to found a firm [52]. All of the turbines for wind power plants are imported in Turkey [55].

In Iran utilization of wind energy is still in its initial stages of development. By 2009, Iran had wind power installed capacity of 91 MW [56]. Alamdari and co-worker [56] studied sixty eight sites to evaluate the most important characteristics of wind energy in the studied sites. In Malaysia the utilization of wind energy sources is limited due to low average wind velocity in the whole country [57]. Likewise the arable plains for wind energy in Korean Peninsula are negligibly small.

13. Localization strategies

International technology transfer is a key element in efforts to ensure low carbon growth in developing countries [58]. Many countries and sub-national governments are looking not only to expand their domestic use of renewable energy, but also to develop accompanying local renewable energy technology manufacturing industries [59]. According to Qiu and co-workers [60] wind farm economies of scale and wind turbine localization rate have also been strong factors driving down the price of wind power in China. In case of wind energy, the costs of wind turbines could decrease by 20–30%, if major parts, such as blades, gear boxes, engines, hydraulic pressure systems, brake high-speed spindles, security crossheads, yawing brakes, etc., were manufactured domestically. To get the benefit of cost reduction renewable energy firms are locating their manufacturing facilities in countries like India and China [61]. Other factor that the impact cost include lower labour costs in some developing countries with manufacturing capacity, the degree of competition in a specific market, the bargaining power of market actors, the national regulation concerning the characteristics of the wind turbine (e.g. the existence of strict grid codes in some regions), the distance and modality of grid connection (including the possibility of having to finance all the cost of a grid upgrade) and the extent of the civil works (which in turn depend on factors such as the accessibility and geotechnical conditions of the site) [42].

World's largest wind turbine manufacturer Vestas of Denmark is setting up research and manufacturing operations in India and China. Although the products are predominantly designed for the specificities of the local market, strategically these production facilities are expected to be utilized as a global manufacturing set up [62]. In coming years, fundamental changes in the location of wind turbine and solar PV manufacturing are expected and R&D base will probably extended away from Europe to emerging economies Like India and China [61].

Beside the strategic decisions of the firms to move to low cost advantages, the location also is related with the existing knowledge, technology and manufacturing base of the host country. High international transfers of low carbon and clean energy technologies are related to strong technology capabilities of China, while the lower rate of international transfer in the case of India is due to its own capability to diffuse domestic technologies [63]. Lewis and Wiser [64] claim that wind turbine manufacturers usually get their head start in their home country markets, a trend that is clear in the largest markets of Denmark, Germany, US, Spain and India. Firms like Vestas (Denmark), Suzlon (India) and Enercon (Germany) that are the world's largest turbine manufacturers have had large and stable home markets. A stable and sizable home market can provide local manufacturers with the necessary testing ground to sort out their technology and manufacturing strategies and experiment with technology designs [64].

China has a local content requirement that mandates a certain percentage of local content for wind turbine manufacturing in some or all projects within the country. But the success of a local content policy requires a large market size in order to lure foreign firms to undertake the significant investments required in local manufacturing [64]. China has sufficient market potential to attract foreign investments particularly competence creating multinationals. The renewable energy market like wind and solar, characteristic of high cost of implementation and low performance, are dependent on policies including production incentives and local subsidies and tax benefits. The local content requirement of Chinese wind development policies [64], and the requirement of local firms in the equity partnership of foreign firms are policies that are attracting multinational companies.

In 2009, Vestas for the first time customized a turbine for a single, specific and low wind resource market. It developed a new V60–850 kW wind turbine design specifically tailored for China, particularly the region of Inner Mongolia. This new design has blade designs and temperature control systems that are adapted to the tough winters of Inner Mongolia. The turbine is most effective in low and medium winds, which make up 75% of China's unutilized onshore wind potential [65]. Over 90% of the new turbine machine's components are Chinese made. All wind turbines have been built in China are above 2 MW of capacity. Vestas is creating a production value chain partnering with 80 odd local suppliers of components for its wind turbines [61].

India, on the other hand, does not have a local content requirement mandate, but has an industrial regulatory environment requiring 51%, more or less, domestic equity ownership in virtually all industries. This mandate is to give domestic firms access to new product and process technologies of the MNCs, and to facilitate the use of local content and skills in the development of the technology by multinational companies [66]. By 2009, the Indian government allowed 100% FDI in the renewable energy sector and approved a generation based incentive scheme in wind power projects for foreign investors who cannot avail benefits of accelerated depreciation available to domestic investors [67].

Wind power program in India is the highly successful and occupies the fifth position in the world having wind power installed capacity of 11.8 GW as on January 2010 [39]. At the end of 2009, India had 10,926 MW of installed wind capacity, and 11,807 MW were reached by the end of the country's financial year on 31 March 2010. India has a solid domestic manufacturing base, with current production capacity of 4500–5000 MW/year. Wind turbine manufacturers operating in India include Indian company Suzlon, which is now a global leader. Seventeen companies now manufacture wind turbines in India and another eight are in the process of entering the Indian wind power market, through either joint venture under licensed production, as subsidiaries of foreign companies or as Indian companies with their own technology. It is expected that the annual production capacity will rise to more than10,000 MW by 2012–2013 [38]. Some of these foreign companies now source more than 80% of the components for their Indian-manufactured turbines from India. Wind turbines and turbine blades have been exported from India to the USA, Europe, Australia, China and Brazil.

A recently published report on 'Wind Power: Opportunities in Emerging Markets' [68] maintains that emerging countries are faced with increasing power demand due to three main reasons. Firstly, most of the emerging economies are preferred destinations for industrial and manufacturing plant set up by developed countries and hence are in the need to electricity. Secondly, development of power grid connectivity has boosted up the power consumption. Thirdly, increasing population has fuelled the power requirement in these economies. Due to rising fossil fuel prices, these countries are adding renewable sources of energy into their power mix. Being a relatively low cost and cleaner renewable energy sources, wind power represents the best choice to feed their growing energy demand and consequently become a highly competitive source for power generation.

For all energy sources, less energy is delivered to the economy than the energy content of the fossil fuels mined because some energy must be diverted for manufacturing, erecting, maintaining and operating the equipment. For ecological sustainability, further energy must be diverted for ecosystem maintenance, to ensure continued delivery of vital ecosystem services. As use of new RE sources such as wind and solar grows, their energy and environmental costs will become increasingly apparent, which suggests that we need to be sparing even in our use of RE [69]. But the longer we delay the transition to RE, the lower will be the maximum value of net green energy that can be delivered(because ongoing climate change-along with any further population and economic growth-will tend to lower the primary energy vs energy ratio (E_R)). Clearly, if E_R is less than 1.0, the energy project is not viable, regardless of the monetary costs of the energy output. In fact, E_R will need to be much greater than 1.0 if the project is to be viable.

14. Wind energy in Pakistan

The study of geographical distribution of wind speeds, characteristic parameters of the wind, topography and local wind flow and measurement of the wind speed are very essential in wind resource assessment for successful application of wind turbines. Pakistan is situated between latitude 24 and 37° North and longitude 62 and 75° East. The country borders India in the east, Iran on the west, China in the north, Afghanistan in the northwest and the Arabian Sea in the south. The total area of Pakistan is 803,950 km^2. Pakistan's coastline is about 1046 km long, extending from Indian border in the east to the Iranian border in the west. According to Pakistan's Alternative Energy Development Board, wind power offers a technical potential of 360 GW, and this is supported by figures from SWERA, which estimate a 349.3 GW potential.

The wind map (Fig. 3) developed by National Renewable Energy Laboratory USA in collaboration with USAID, has indicated a potential of 346 GW of wind energy in Pakistan. About 3% of Pakistan's total land has been classified as Class 4+ with of potential 132 GW (assumes 5 MW/sq km). In Pakistan, the potential of wind power has so far not been utilized significantly. So far only 6.175 MW of wind energy has been installed in the country

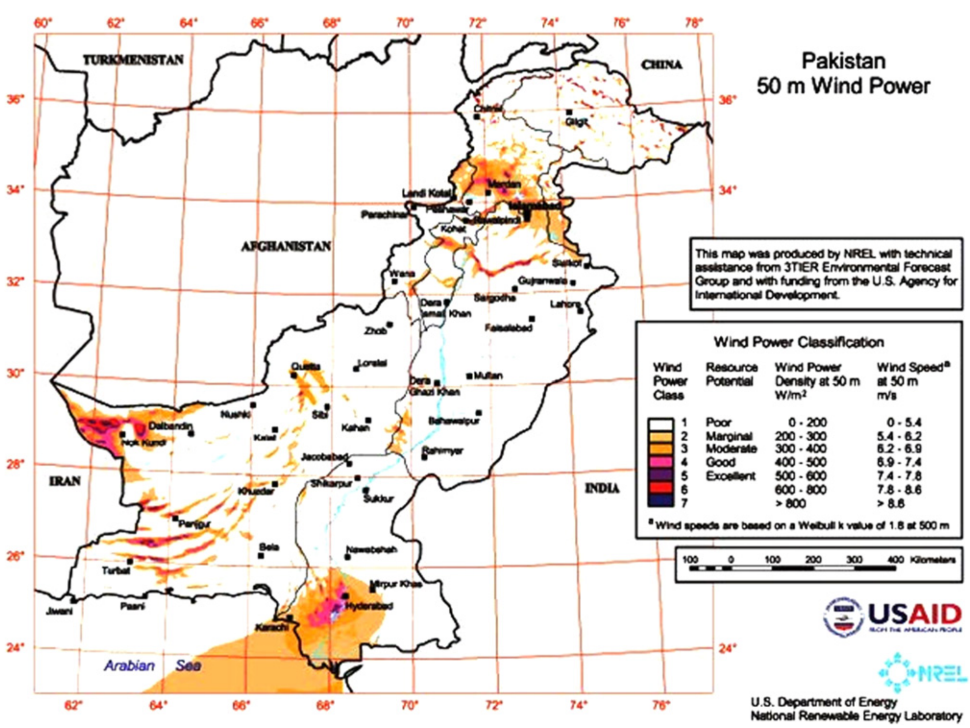

Fig. 3. Wind map developed by National Renewable Energy Laboratory (NREL), USA in collaboration with USAID.

at various locations which are providing electricity directly to the National Grid [70].

During 2009, Pakistan's Alternative Energy Development Agency announced its aim to source a 14% share of the national energy mix from renewable by 2022. This implied a cumulative capacity addition of 17 GW of renewable energy. The majority of this is likely to come from wind power. The core aim of the proposed policy is to make Pakistan self-sufficient in energy supplies by adding capacity from different sources, including renewable. The country had only 42 MW of grid -connected renewable energy in 2009 and plans to add another 100 MW this year [40]. Wind energy has the advantage that it can be utilized independently, and deployed locally in rural and remote areas. Thus the location far away from the main grid finds wind suitable for generating electricity and pumping water for irrigation purpose [71]. Large grid-connected wind farms can help alleviating power shortages in general. The living standard will go up and environment quality will improve with the development of wind energy resource. The reliance on imported oil will decrease, which, in turn, will enhance the energy security of the country [72].

The very first efforts to identify possible exploitation of wind energy for water pumping and aero-generation in Pakistan were made in 1980s [73]. However, until now, wind energy did not manage to make significant inroads in Pakistan mainly due to non-availability of reliable long term surface wind speed data. In order to facilitate the growth of wind energy and to minimize the uncertainties related to wind data, AEDB along with UNDP under the GEF funded Wind Energy Program, started to install wind measuring masts in the potential wind energy areas of Pakistan. In the first phase of this project AEDB and UNDP (WEP) has installed five masts in the Gharo–Keti Bandar Wind Corridor (Fig. 4) identified by AEDB and PMD. The results of the analyses of wind data obtained at 80 m from the three sites namely Baburband, Keti Bandar and Hawksbay-KPT height for these sites are given in Table 3.

14.1. The Gharo–Keti bander—hyderabad wind corridor in Sindh

An evaluation of the wind resource available at Kati Bandar on the coast of Sindh by [74] shows that it is a class 4 wind power site, indicating its suitability for both large and small wind power projects. During summer six months April–September, there are strong sustainable winds mostly from Southwest and during this

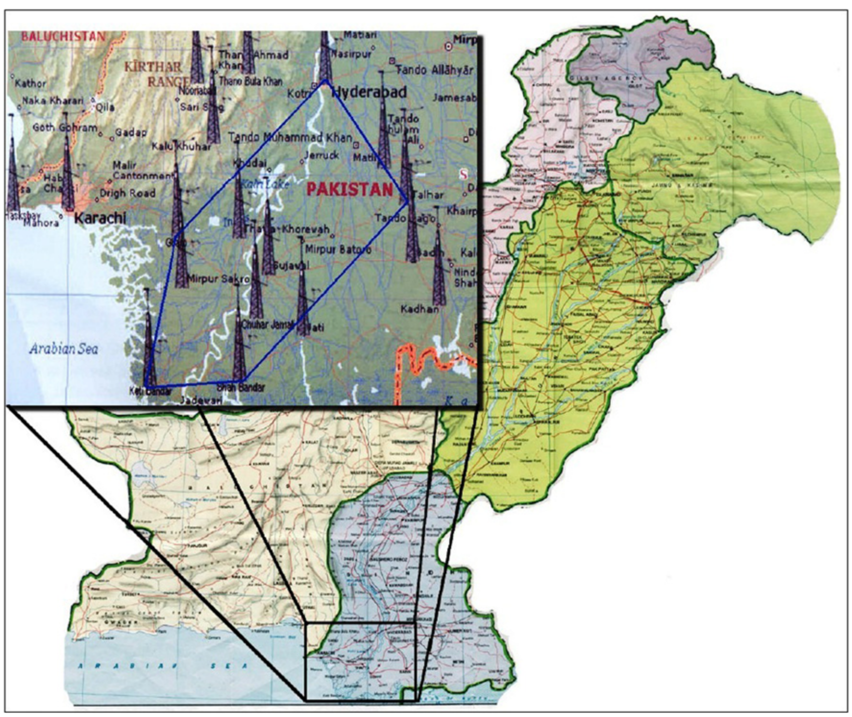

Fig. 4. Five (05) masts in the Gharo–Keti Bandar Wind Corridor identified by AEDB and PMD.

Table 3
Wind data obtained at 80 m from the three sites namely Baburband, Keti Bandar and Hawksbay-KPT [54].

Sites	Mean annual speed (m/s)	Weibull shape factor (k)	Remarks
Baburband	7.1	2.6	Site is the highest potential wind area in comparison with the other two sites. Its annual average wind speed at 80 m height from ground is 7.1 m/s. The shape factor (k) of the Weibull distribution for the site data is 2.6; this indicates that the distribution is relatively close to the mean value which ensures high production efficiency.
Keti Bandar	6.9	3.6	site is also a high potential area; it has the annual average wind speed at 80 m height from ground of 6.87 m/s. Practical experience and analysis of the site suggest that Keti Bandar site could achieve the long term annual average wind speed of around 7.0 m/s. The shape factor (k) of the Weibull distribution for the site data is 3.6, indicating that the distribution is close to the mean value which ensures high production efficiency.
Hawksbay-KPT	5.9	3.23	Site has the lowest potential for wind energy in comparison with the other two sites. It has an annual average wind speed at 80 m height from ground of 5.9 m/s. The shape factor (k) of the Weibull distribution for the site data is 3.23, indicating that the distribution is not dispersed which improves the production value at this wind speed.

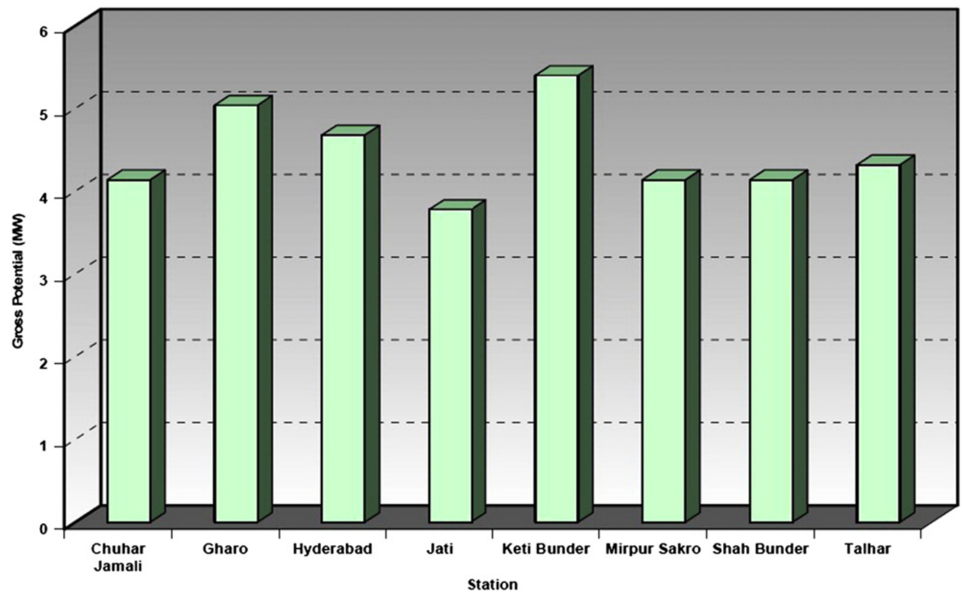

Fig. 5. Gross Wind Power Potential (MW) per km^2 of Different Sites in Sindh.

Table 4
The exploitable electric power generation potential of wind corridor.

Total Area of Sindh suitable for wind farms	9749 km^2
Average Capacity Factor of this area in Sindh	25%
Wind power potential of 18 MW Wind Farm on 1 km^2 area when Capacity Factor is 25%	$18 \times 0.25 = 4.5$ MW
Gross Potential of the area corresponding to 25% Capacity Factor	11,000 MW

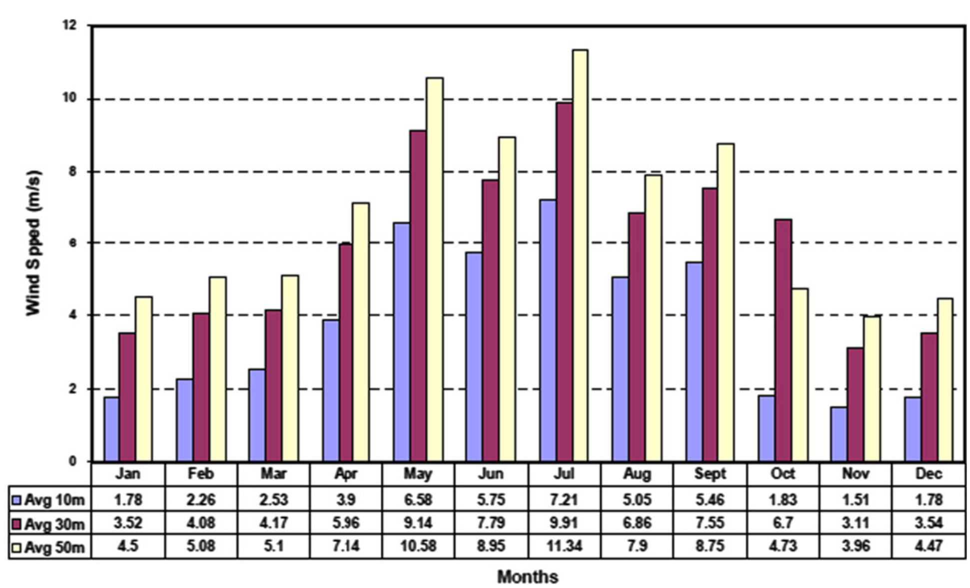

Fig. 6. Monthly Average Wind Speed (m/s) at Gharo.

high capacity factor of 32–50% could be achieved [75]. In this period local power demand is also very high due to extreme summer season. Pakistan Meteorological Department (PMD) also conducted a detailed Wind Power Potential Survey of Coastal Areas of Pakistan. The study suggests gross wind power potential of Sindh coastal areas is 43,000 MW. The Gross Wind Power Potential (MW) per square kilometer of Different Sites in Sindh is shown in Fig. 5 [76]. The Gharo–Keti Bandar wind corridor spread 60 km along the coastline of Sindh Province and more than 170 km deep towards the land. These areas have coverage of 9700 km^2. The land is totally un-inhabited and there is no issue of loss of habitat and resettlement. There is no wild life sanctuary, protected area, wild life park or known habitat of any kind, especially there is no endangered species in the region, mainly due to scarcity of water. The ground water also is very deep approx. at 115 m (350 feet) depth. However, it was found that the wind resource was strongly seasonal in character with the monsoon months producing the most significant energy yields [77].

Keeping in view the area utilization constrains etc. the same study has identified Wind Corridor in Sindh as a resource of high

Table 5
Status of IPPS for wind power generation projects of 50 MW wind corridor in Sindh [59].

Sr. No.	Company	Location of land	Status
1.	New Park Energy Ltd	Gharo	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License • NEPRA has awarded a tariff of US Cents 10.2852 per kW h • submitted Performance Guarantees and subsequently acquired Letter of Support (LOS) from AEDB
2.	Dawood Power Ltd.	Bhambore	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License • NEPRA has awarded a tariff of US Cents 11.87 per kW h • Estimated investment USD 120.34
3.	ZorluEnerji Pakistan Ltd (ZEPL)	Jhampir	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License • NEPRA has awarded a tariff of US Cents 12.1057 per kW h • Standard draft Energy Purchase Agreement (EPA) prepared by AEDB, is under negotiations with NTDC • submitted Performance Guarantees and subsequently acquired Letter of Support (LOS) from AEDB • Estimated investment USD 121.99
4.	TenagaGenerasi Ltd.	Kuttikun	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License
5.	Green Power (Pvt) Ltd,	Kuttikun	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License • NEPRA has awarded a tariff of US Cents 10.28 per kW h • Standard draft Energy Purchase Agreement (EPA) prepared by AEDB, is under negotiations with NTDC • Estimated investment USD 108.8
6.	Master Wind Energy Ltd,	Jhampir	• AEDB has so far allocated land • Feasibility studies submitted
7.	Zephyr Power Ltd	Bhambore	• AEDB has so far allocated land • Feasibility studies submitted
8.	Beacon Energy Ltd.,	Kuttikun	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued Generation License • NEPRA has awarded a tariff of US Cents 12.5 per kW h • Standard draft Energy Purchase Agreement (EPA) prepared by AEDB, is under negotiations with NTDC • Estimated investment USD 130.0
9.	Fauji Fertilizer Company Ltd.	Jhampir	• AEDB has so far allocated land • Feasibility studies submitted • NEPRA has issued generation license • Standard draft Energy Purchase Agreement (EPA) prepared by AEDB, is under negotiations with NTDC • Estimated investment USD 143.0
10.	Arabian Sea Wind Energy Pvt. Ltd.	Lakha	• AEDB has so far allocated land • Feasibility studies submitted • Estimated investment USD 142.23
11.	Lucky Energy (Pvt) Ltd	Jhampir	• AEDB has so far allocated land • Feasibility studies submitted • Estimated investment USD 132.0
12.	Sapphire Wind Power Company (Pvt) Ltd,	Jhampir	• AEDB has so far allocated land • Feasibility studies submitted
13.	Makwind Power Pvt. Limited.	Jhampir	• In process of purchasing their own land • Feasibility studies submitted
14.	Zeni Wind Power Pvt. Limited.	Jhampir	• In process of purchasing their own land
15.	CWE	Jhampir	• AEDB has so far allocated land

Table 5 (*continued*)

Sr. No.	Company	Location of land	Status
16.	Wind Eagle Ltd. (Technology Plc Ltd),	Jhampir	• AEDB has so far allocated land
17.	Metro Power Co. (Pvt)	Jhampir	• AEDB has so far allocated land
18.	Gul Ahmed Energy Ltd,	Jhampir	• AEDB has so far allocated land
19.	HOM Energy (Private) Ltd,	Jhampir	• AEDB has so far allocated land
20.	Sachal Energy Development Pvt Ltd,	Jhampir	• AEDB has so far allocated land

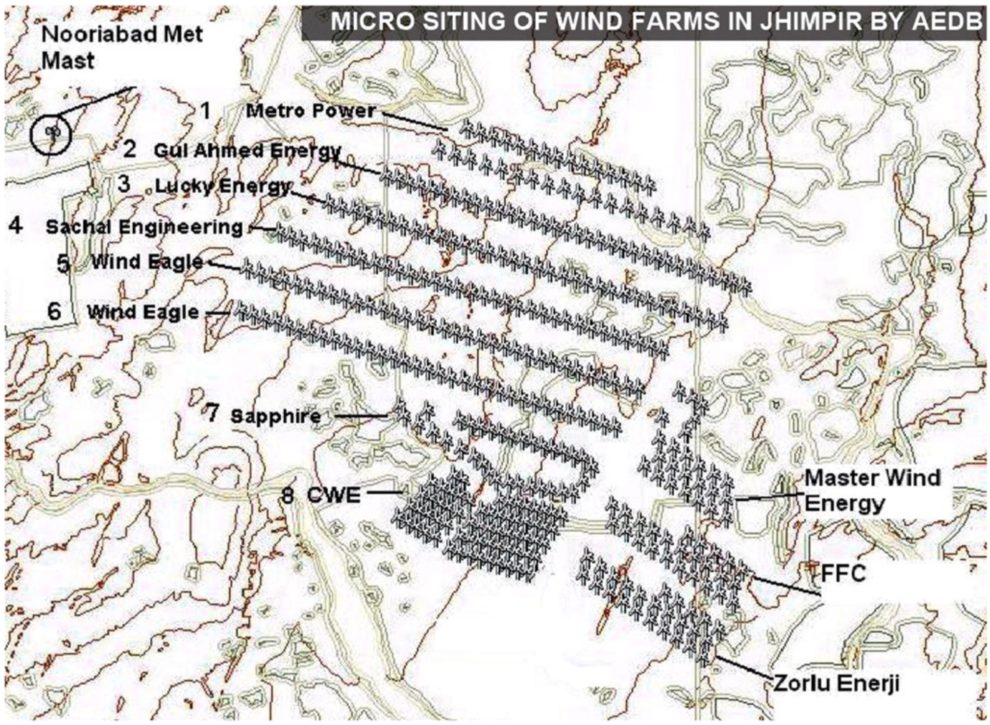

Fig. 7. Micro siting of wind farm in Jhimpir by AEDB.

wind regimes (Fig. 5). The exploitable electric power generation potential of wind corridor is estimated to be about 11 GW with capacity factor of 25% (Table 4) [76].

Gharo is one of the sites in Sindh where the wind data have been recorded and studied by PMD. The wind measurements at Gharo have been carried out for 24 months. Monthly Average Wind Speed (m/s) at Gharo is given in Fig. 6. The annual mean wind speed is estimated to be 6.86 m/s at 50 m above ground level. The annual power density of area is 408.6 W/m^2, which brings the site into good category of power potential meaning that area is suitable for large economically viable wind farm [76].

Projects with a cumulative capacity of 900 MW are at various stages of development along the Ghard–Keti Bandar wind corridor in Sindh. Forty eight national and international private investors currently possess letter of intent (LOI) for wind power projects issued by AEDB. AEDB has so far allocated land to eighteen wind IPPs for wind power generation projects of 50 MW each while two IPPs are in process of purchasing their own land in the wind corridor. Thirteen IPPs submitted the feasibility studies for their projects and NEPRA has so far issued Generation License to six IPPs. The details of status of these project are shown in Table 5 [78]; while the Micro siting of wind farm in Jhimpir by AEDB is given in Fig. 7.

AEDB has conducted regional EIA Study and Grid Integration Studies of Gharo wind corridor and has developed guidelines for the preparation and review of EIA studies through UNDP funding. Amendments in Grid Code specific to wind energy have been finalized. These are in final stages of approval in NEPRA [70]. Out of above projects Turkish company Zorlu Enerji Pakistan Ltd (ZEPL) has installed 5 wind turbines of 1.2 MW each installed at Jhampir, Sindh and is providing 6 MW electricity to HESCO Plant (Fig. 8) which will be upgrade to 50 MW within the next year [70].

Fauji Foundation has entered into an agreement for equity commitments of approximately PKR 6 billion to establish two wind farms of 50 MW each at Gharo Sindh with total project cost estimated to be USD 260 million. These two Projects will be implemented through Foundation Wind Energy-I Limited (formerly Beacon Energy Limited) and Foundation Wind Energy-II (Pvt) Limited (formerly Green Power (Pvt) Limited). FFC Wind Energy has already achieved Financial Close and operation of this wind farm is expected to commence by June 2012 [79]. Fauji Fertilizer Company has also signed a wind turbine supply agreement with M/s Nordex, a reputed wind turbine manufacturer, in March 2010 for its 50 MW wind power project. As per the deal, Nordex will supply 33 state of the art Nordex S77–1.5 MW wind turbine generators for this project. Through this turbine supply deal Nordex is entering into a new developing wind energy market of Pakistan. The presence of Nordex in Pakistan will benefit both Nordex and wind IPPs to develop new ventures/ deals for bringing wind energy in Pakistan [80]. Since Wind turbines are not available off-the-shelf in the world market, AEDB has convinced the four top OEMs—GE of USA, VESTAS of Denmark, Gamesa of Spain and Fuhrlander of Germany—to reserve the equipment needed to produce 50-MW in Pakistan.

Fig. 8. Zorlu Wind Farm (6 MW) at Jhampir–Sindh [59].

14.2. Wind power competitiveness to conventional grid in Pakistan

Mirza et al. [81] has discussed the Barriers to renewable energy development in Pakistan and suggested that if fossil fuel subsidies are removed and environmental damage costs are taken into account, renewable resources are likely to have comparable or even lower costs than fossil fuels. Indigenization of renewable energy technologies can reduce the investment costs significantly.

The cost of a small turbine is generally around Rs. 50 mn per MW while a large turbine costs around Rs. 60 mn per MW. The cost of generation varies from site to site depending on the wind resources and from year to year due to variations in the wind speed. Other main factors governing wind power economies in the country are capital costs, operation and maintenance cost, turbine life and the discount rate which reflects the cost of capital. Cost per unit of electricity generated from 15 MW wind farms at 40 locations in the Coastal area of Pakistan has been estimated by Harijan et al. [82] using the Nordex N43/600 wind turbine as reference wind turbine and wind duration curves in 2009. The estimated per unit cost of electricity generation from wind power as 4–5 ¢/kW h in Sindh coastline and 7–11 ¢/kW h in Balochistan coastline. In Sindh province, the minimum cost of electricity generated was found to be 4.2 ¢/kW h at Jamshoro, while the corresponding maximum was 7.4 ¢/kW h at Kadhan site. In Balochistan, the minimum cost of electricity generated was found to be 6.3 ¢/kW h at Aghore, while the corresponding maximum was 21.0 ¢/kW h at Mand site. The study concludes that at most of the locations in the coastal area of Pakistan especially in Sindh province, wind power is competitive to conventional grid connected thermal power even without considering the externalities [82]. The projects have estimated to have a payback period of five-eight years.

14.3. Wind power systems for remote rural community

Through the field study it was learned that almost no impact of renewable energy technologies have been reached to the doors of larger population in Pakistan as very few initiatives for renewable energy resources have been reported involving local people [83,84]. In the year 2002, 14 small wind turbines, six of 500 W each and eight of 300Weach, were procured from China and installed by PCRET for demonstration purpose. Out of these, eight were installed in the coastal belt of Balochistan and six were installed in the coastal areas of Sindh. That demonstration project concluded successfully-these small wind turbines have been found to be both technically and economically viable for electrification of the remote communities [72]. Small wind turbines offer a promising alternative for many remote electrical uses where there is a good wind resource. Small wind turbines can play in supplying remote power needs by both testing and developing new applications for small turbines. The energy needs of small rural communities fall into three main categories [85]:

(i) Energy to improve living conditions
(ii) Energy to improve agricultural productivity
(iii) Energy for small scale industries.

A 10 kW power generation capacity wind mill for example, is more suitable in the context of Pakistan rural scene and is sufficient to meet the electricity needs of 200–300 people living in a village. It is observed that the energy generated by a wind mill could be twice as efficient as that obtained from a diesel generator [86].

Small scale wind energy systems have the potential for considerable improvement in the standard of living of individuals in rural areas in the developing countries. Local manufacture and servicing are important for the success of the transferred technology. A conventional lead-acid car battery may be a cheap and reliable source of electrical power for small rural household applications.

More than 62% of the population in Pakistan lives in the rural areas, where access to commercial energy resources is limited and traditional methods of using wood, animal waste and crop waste for domestic fuel needs are the only choice. Although village electrification program has been the central objective of the total power sector development programs, but there is no firm government policy for the development of decentralized power supply [87,88].

Wind energy drive pumps can be used for different applications; for domestic and agricultural applications including domestic water supply animal husbandry, irrigation, drainage and salterns. Similarly, a 500 W turbine can sufficiently improve the quality of life for such areas and would be sufficient to run about two fans, two bulbs, a TV/radio, charging batteries etc., giving people access to electrical lighting, and other household conveniences. Although the design of a wind-powered battery charging station can be more complex (because of the nature of the wind resource), wind-powered stations offer greater economy of scale. Wind power systems have major potential applications in remote rural community not connected with national grid for:

- Generating electricity for smartgrid decentralized energy systems
- Performing agricultural tasks such as running floor mill, grinding corn, crushing sugarcane, threshing and wood cutting,
- Generating electricity to operate water pumps for large-scale irrigation and for water pumping for small communities, in combination with diesel back-up and/or energy storage systems.

Average wind speed for some selected sites is not enough for wind power generation to be feasible, although the wind speed

can still be utilized to run wind mills to pump water for the areas where it is available at short depths up to 30 m.

14.4. Government incentives

Government of Pakistan's ''Policy for Development of Renewable Energy for Power Generation'' offers the following incentives [78]:

- Wind risk in certain areas (risk of variability of wind speed).
- Guaranteed electricity purchase.
- Grid provision is the responsibility of the purchaser.
- Protection against political risk.
- Attractive Tariff (Cost plus with up to 17% ROE), indexed to inflation and exchange rate variation (Rupee/ Dollar).
- Euro/Dollar parity allowed.
- Carbon credits available.
- No Import duties on equipment.
- Exemption on income tax/Withholding tax and sales tax.
- Permission to issue corporate registered bonds.

PMD in Phase-II is conducting Wind Power Potential Survey of Northern Areas of Pakistan since July 2005. PCAT installed more than two dozen imported and locally made windmills for pumping water at many locations in Sindh and Balochistan. The experiment suffered due to low-quality mills and lack of proper infrastructure for maintenance [89]. A local manufacturer (Merin Ltd., Karachi) is making windmills that lift 10,000–22,000 gallons of water per day from a depth of 70 ft. The manufacturer claims to have exported windmills and installed 24 of these locally. Some of windmills were supplied to Abu Dhabi and installed in the desert areas to supply drinking water for human and animals [90].

Ministry of Environment, through a US$471,900 support from the Global Environment Facility (GEF), Nordic Trust Fund, and UNDP, initiated a project entitled Commercialization of Wind Power Potential in Pakistan [91]. The project is aimed at determining the feasibility for the country's first wind power project in the southwestern coast of Balochistan. The town of Pasni along Makran coast was selected for this study. Wind speed measurements were started in early 2002 and continued for 20 months. This project later became part of a new comprehensive project named Sustainable Development of Utility-scale Wind Power Production, Phase 1. With a total financing of US$4,195,931, it was scheduled to commence in July 2004 tentatively. Phase 1 will take 2 years to complete and if the outcomes are positive, then Phase 2 would be initiated. In Phase 2, a 15-MW wind farm would be developed over a 3-year period, which would be connected to the isolated small Makran grid.

14.5. Presence of foreign firm in local market

Many foreign firms in Pakistan appoint local agents to provide market intelligence and to facilitate distribution. These agents typically work on a fixed commission, which can range from two to 10% for plant and equipment purchases and from 15 to 20% for spare parts. Commissions may be computed on Freight On Board, ex-factory, or Cost, Insurance and Freight basis, as mutually agreed. Some agents prefer to have suppliers quote net prices to them and they, in turn, add the commission to arrive at their selling price. Other agents operate as consultants on a retainer ship basis, receiving their fee regardless of the volume of total sales.

Many foreign principals appoint one or more agents/distributors to cover the entire country; at times foreign principals work through a regional office to cover this market. Several U.S. and EU firms cover Pakistan through their offices in Dubai and Singapore.

Joint ventures can be an attractive option in Pakistan, as there are many local entrepreneurs who have built a substantial base in their industrial enterprises and are seeking to combine their knowledge of local markets with foreign capital and technology. The foreign joint venture partner limits its initial country exposure while enjoying the support of a local partner in a new market. Prominent joint ventures have been established in the automobile, fertilizer, electronic, financial services, and food and consumer product sectors.

14.6. Indigenous manufacture of components of wind power plant in Pakistan

The wind turbine constitutes the single largest cost component and this cost is lower in emerging markets, notably China and India. Pakistan has set target to add a cumulative capacity of 17 GW of renewable energy by 2022 which imply a stable and sizable domestic market for potential local manufacturers with the necessary testing ground to sort out their technology and manufacturing strategies. The turbine manufacturer Fuhrländer of Germany has signed an agreement with Alternative Energy Development Board (AEDB) of Pakistan, to manufacture wind turbines in Pakistan to help establish wind power projects. German Company, Fuhrländer, would transfer the technology to Pakistan for manufacturing of wind turbines along with its accessories [78]. In this regard country can seek collaboration of Suzlon, who has developed and implemented several large-scale wind farms throughout India, can be utilized to customize a turbine for a single, specific and low wind resource market. Suzlon is a fully integrated wind power company that provides customers with consultancy, design, manufacturing, operation and maintenance services and expanded its presence. County can follow the policy of local content requirement that mandates a certain percentage of local content for wind turbine manufacturing in some or all projects within the country.

Presently one local manufacturer, Merin Limited., is making windmills for water lifting. This company sells these mills locally and also to abroad. One wind mill also made by COMSATS Institute of Information Technology for the training purpose under the supervision of UK Engineers and Installed at CIIT, Abbotabad Campus on August 2007. The existing facilities in engineering organizations within the country can be augmented and upgraded to their optimum level for manufacturing part of the wind turbine. Details of capability of existing engineering organizations are given in Table 6 Instead of setting up manufacturing facilities for each and every part of the wind turbine or requirement of local firms in the equity partnership of foreign firms are policies that are attracting multinational companies. The renewable energy market like wind is dependent on policies including production incentives and local subsidies and tax benefits. Pakistan can adopt the strategy of encouraging local components in wind turbines since the country is in its early phase of utilizing wind energy. In more practical terms, government can define locally manufactured wind turbine as those consisting at least 40% components by local suppliers. Educational institutions in country can play a vital role in training engineers and scientists, by organizing intensive workshops and training courses. They can also provide testing facilities for measuring wind power characteristics and evaluation of appropriate small scale wind energy systems to help local industries in identifying design problems. Stable institutional support from intermediaries such as the local/ national government or NGOs is necessary to foster the development of a wind power industry based on local manufacture. The roles of these intermediaries include identifying and targeting windy areas with favourable environmental conditions, conducting research and development, collecting feedback

Table 6
Details of capability of existing engineering organizations in Pakistan.

Engineering organization	Business type and existing capability	Remarks
Pakistan Machine Tool Factory (Pvt) Ltd. PMTF Road, Off National Highway, KARACHI-75030Pakistan.	• Designing, machining, forging, Heat treatment, assembly, die casting etc. • Tools, automotive transmissions and axles components, gears for locomotives, pressure die cast parts • Gear and shafts • Traction gears and pinions for locomotives • Gears for various industrial applications • Components for bedford trucks & buses etc • Spares for various plants/machinery. • Machines/equipment as per customer's design/ requirement.	Pakistan Machine Tool Factory (Pvt) Ltd. (PMTF) is a precision engineering goods manufacturing enterprise in Pakistan, established in technical collaboration with M/s. OerlikonBuhrle& Co. of Switzerland who are the world's renowned manufacturers of Machine Tools. The factory came into regular production in 1971. PMTF is certified to ISO 9001.Quality Assurance System and has excellent Quality Control and Testing facilities to meet the international quality requirement. Presently engaged in the production of Machine Tools, Automotive Transmissions and Axles Components, Gears for Locomotives, Pressure Die Cast parts and other products and its facilities include Designing, Machining, Forging, Heat Treatment, Assembly, Die Casting etc.
Heavy Electrical Complex (Pvt.) Ltd. Industrial Estate Hattar,KotNajibullah (KPK), Haripur, Pakistan	• Power transformer • Disconnectors 66–220 kV • Circuit breakers 66–132 kV • Instrument transformers 66–132 kV • Lighting arrestors 11–220 kV • Power factor improvement panels 380–440 kV	HEC is one of Pakistan's heavy capital electrical engineering manufacturing industries. It has to manufacture host of electrical products including grid Station equipment, high module transformrs (220 kV and 500 kV) and generator, instrument transformers Completely in-house designed, tested and qualified 31.5/ 40 MV A, 132/11.5 kV power transformers.
Heavy Mechanical Complex (Private) Limited. Taxila, Distt. Rawalpindi, Pakistan	• Turbine/generator parts • Electric overhead traveling crane, portal & mobile cranes. • Iron & steel castings as per specifications • Shafts, rings and others as per specifications • Developed double and single reduction L.S. gearing upto 850 kW • Turbine involute casing • Turbine pit liner • Turbine stay ring • Turbine head cover • Turbine bottom ring • Turbine discharge ring • Turbine spiral casing • Draft tube • Wicket gates • Penstocks • Electric/manual cranes • Track for crane • Gates all types • Generator components • Steel structure • Axles • Screw Jacks • Screw couplings	Heavy Mechanical Complex (Private) Limited is a leading engineering manufacturing enterprise in Pakistan. HMC can manufacturing Main shaft, gear box, Rotor blades, Main frame, Rotor bearings, Screws All its processing facilities are in-house including Designing, Fabrication, Machining, Iron and Steel Castings, Forgings, Heat Treatment, Assembly, Sand Blasting, Painting and Galvanizing etc. Designing, fabrication and & Steel Structures mission and Distribution of galvanizing of 11 kV, 66 kV, 132 kV, 220 kV and 500 kV distribution and transmission line towers according to international standard. HMC can undertake the complete project on turnkey basis and can supervise the erection, which means that HMC's experts and technicians remain on site throughout, ensuring that each part of equipment is installed according to the laid down requirements. HMC's experts help and supervise the entire project from erection to commissioning.
Pakistan Engineering Company limited (PECO) 6-Ganga Ram Trust Building, Shahra-e-Quaid-e-Azam, Lahore, Pakistan	• Electricity transmission line towers (11 kV, 132 kV, 220 kV and 500 kV transmission line towers) • Switch yard structures • Design facilities for microwave guy rope antennas, Telecommunication towers • High tensile and mild steel angles • 3 phase squirrel cage type induction motors • Deep well and submersible turbines and pumps (All castings and components of pumps are manufactured In house) • Electric motors (All components of electric motors are manufactured in house)	PECO has all in house facilities for production of towers, i.e. steel making, steel re-rolling, fabrication, galvanizing and testing. The product line consists of 11 kV, 132 kV, 220 kV and 500 kV transmission line towers. PECO is the only company in Pakistan which produces 500 kV transmission line towers. PECO has in house computer aided design and drafting facilities. A large number of design engineers and drafting personnel, highly experienced in relevant fields are engaged in designing the economical designs of Transmission Line towers and Switch Yard Structures for any level of voltage between 11 kV to 500 kV.
Pakistan Cables	• General wiring single core cables from 1 mm^2 to 10 mm^2 • Larger single core cables from 16 mm^2 to 70 mm^2 • Multi-core cables from 1 mm^2 to 10 mm^2 • Flexible multi-core cables from 1 mm^2 to 4 mm^2	Pakistan cables manufactures and market the general wiring cables in the range of 250/750 V conforming to BSS: 6004:95
Siemens (Pakistan) Engineering Co. Ltd B-72 Estate Avenue, S.I.T.E, Karachi 75700, Pakistan.	• Equipment & substations for power transmission & distribution systems. • Power supply and distribution systems • Power transformers • Geared motors • Switchgear. • Motors and drives • Cables, cable trays	Siemens offers integrated solutions and services that meet the demands of the entire wind energy conversion chain. Design & engineering for complete wind turbine, Power converter, Transformer

Table 6 (*continued*)

Engineering organization	Business type and existing capability	Remarks
	• Energy meters • Power quality recorders • Power transmission and distribution network • Steel structure fabrication & Erection. • Installation & alignment of rotary and stationary Equipment • Painting & insulation works. • Civil construction	
DesconEngineering (Private) Limited. 18 km Ferozepur Road, Lahore, 54760, Pakistan	• Stainless teel equipment • Transport equipment • Steel structure • Project management, engineering, construction, maintenance and manufacturing	Descon engineering is a multi-dimensional engineering, construction and manufacturing company operating in Pakistan. The company specializes in providing high quality basic and detailed engineering services; other significant capabilities include services for life-cycle estimation & costing, project management, engineering software, plant start-up and training. Descon has six manufacturing facilities strategically located in the UAE, Saudi Arabia and Pakistan to provide our valued customers with cost effective and swift solutions. These are applicable to a wide variety of projects related to Industrial plants, Energy and Infrastructure development for which services are provided selectively or on turnkey/ EPC basis.
AGECO (Pvt.) Ltd. 7 & 8, First Floor, Hill View Plaza, Blue Area, Islamabad, Pakistan	• Vertical axial wind turbine 2 kW, 5 kW and 10 kW.	Supplies the indigenous design and locally manufactured vertical axial wind turbine 2 kW, 5 kW and 10 kW. A wind energy vertical turbine has been designed by the AGECO Firm which operates at availability of wind in range of 2.1 m to 7 m/s against the maximum required range of 3.5 m/s to generate 1.5 to 2 kW of energy in 24 h. The locally designed wind energy turbine will cost Rs. 200,000 per kW as compared to imported turbine costing Rs. 1 million per kW.
Bolan Castings Limited F-1, Hub River Road, S.I.T.E., Karachi, Pakistan	• Modern and well-equipped foundry	Currently producing tractors and automotive castings in grey and ductile iron like engine blocks, Cylinder heads, Gearboxes, Axle housing, Hubs and Brake drums, etc.
Atlas Battery Limited D-181, Central Avenue,S.I.T.E., Karachi-75730, Pakistan	• Dry charged Hard Rubber batteries • Polypropylene and hard rubber batteries	Atlas Battery Limited pioneered the manufacture of dry charged Hard Rubber batteries in Pakistan. The company manufactures a complete range of Polypropylene and hard rubber batteries.
EXIDE Pakistan Limited A-44, Hill Street, Off Manghoopir Road, S.I.T.E, Karachi-75700, Pakistan	• Lead acid electric torage batteries	EXIDE Pakistan manufactures special application Industrial Batteries for Stand-by Power. Company owns 50 metric tons of Sulphuric Acid per day.
Pak Elektron Limited (PEL) 14-km, Ferozepur Road, Lahore	• Transformers of ratings 31/40 MV A, 20/26 MV A, and 10/13 MV A for ratings up to 132 kV • 1, 2.5, 3.3, 5.2 kV A Generators kV A • Single phase static energy meter used for measurement of active (kW h) energy for Domestic & commercial consumers • MV & LV Switchgear are produced for indoor and outdoor installations.	Pak Elektron Limited (PEL) is the pioneer manufacturer of electrical goods in Pakistan.
Hussan Engineers 132.G.T Road, Baghbanpura, Lahore 54920, Pakistan	• Auto parts for auto engines, of trucks, cars, tractors, generators and Fork lifters of all types	Company is working on the development of high quality auto parts and sub assemblies of different types of engines.
Thal Engineering Plot No. 1, 2, 25 & 26, Sector 22 Korangi Industrial Area, Karachi, Paksitan	• Harness manufacturers	Established in 1996 starting with Auto Air conditioners and subsequently added Wiring Harness, Heater Blower and AC Controls to it product line. Harness manufacturers in Pakistan.
Pakistan Aeronautical Complex (PAC), Kamra	• PAC produces rubber washers, sealing rings and seals	The complex houses multi faceted engineering capabilities which enable it to undertake Aircraft structure overhaul, Aircraft component overhaul, Aircraft Engine overhaul, Radar & Avionics maintenance and overhaul. The factory produces rubber washers, sealing rings and seals.
Millat Equipment Limited 10-km, Raiwind Road, Lahore–Pakistan.	• Manufacturing broad range of transmission shafts, pur gears, helical gears, piral & straight bevel gears and sub assemblies, like hydraulic pump, for massey ferguson brand of tractors.	Millat Equipment Limited, an ISO 9001:2008 certified company, is among the most technologically advanced Transmission Gears & Shafts Manufacturing Company in Pakistan.
Bawany Metals Ltd. 1001, Unitower, I.I Chundrigar Road, Karachi., Pakistan	• Supplier and manufacturer of electrical conductor rod in Pakistan • Manufacture aluminium rod according to international standards.	Bawany Metals Ltd., was founded in 1985, is located at Hub Chowki in Balochistan. The first Copper Rod manufacturing Plant in Pakistan.

Table 6 (*continued*)

Engineering organization	Business type and existing capability	Remarks
		Bawany Metals Ltd., is manufacturing copper rod in Technical Collaboration Furukawa Electric Co.,of Japan, according to the International Standards. Bawany Metals Ltd., has selected the CCR CONTINUUS PROPERZI SYSTEM of manufacturing electrolytic Copper Rod, with capacity of 18,000 M. Tons per year.
Pioneer Cables Ltd. 1001, Unitower. I.I Chundigar Road, Karachi, Pakistan	• High tension cables upto 15 kV. • Overhead conductors AAC & ACSR • Bare copper conductors • General wiring PVC Insulated • Automobile cables • Control cables • Flexible cables • Low tension power cables • Low tension XLPE insulated power cables • Quadruplex cables • High tension XLPE power cables • Polythylene insulated cables • Air field ligthing cables • Specialized cables all types • Introducing tripple extrusion XLPE power cable	First manufacturer to produce triple extruded high tension cables as per IEC 60502-2 specifications. M/s Bawany metals Ltd which is also producing Aluminum Rod 99.5% confirming ASTM B-233.
Pakistan Steel Bin Qasim, Karachi 75000, Pakistan	• Pakistan steel's high quality billets are used for manufacturing plain, deformed, twisted and ribbed bars., manufacturing steel sections viz, rails, angles, joints, channels, squares, flat bars, rods, wire rods, bailing hoops, tees and chains etc, manufacturing seamless pipes, manufacturing of machine components., forging and stamping, manufacturing of spring steel flat bars.	*****
Peoples Steel Mills (PSM) Limited Manghopir, Karachi-75890, Pakistan	• Produce forgings, plates and bars in various sizes.	Peoples Steel Mills (PSM) Limited is the only facility of its kind in Pakistan engaged in the development and production of alloys and special steels
National Transmission &Despatch Company (NTDC) Limited, Room # 414, WAPDA House Shahrah-e-Quaid-e-Azam, Lahore, Pakistan	• NTDC operates and maintains nine 500 kV Grid Stations, 4160 km of 500 kV transmission line and 4000 km of 220 kV transmission line in Pakistan owned by Pakistan Water and Power Development Authority (WAPDA)	****

from end users, creating supply chains for new parts and materials and developing relevant knowledge and skills [92]. Major energy consumer like fertilizer, sugar, textile and cement Industry may be encouraged for setting up wind farms within factory premises. These industries need heavy power and as such wind farms came handy for captive power consumption, of power cuts during summer months was a handicap for industries

14.7. *Incentives for wind turbine manufacturer in Pakistan*

Incentives for wind turbine manufacturer to produce cost effective wind turbines suited specially for the Pakistan's grid and wind conditions.

- Concession on import duty on specified wind turbine parts
- 80% accelerated depreciation over one or two years
- 10 year income tax holiday for wind power generation projects
- Excise duty relief on certain components
- Wheeling, banking and third party sales, buy-back facility by states
- Guarantee market through a specified renewable portfolio standard in some
- Reduced wheeling charges as compared to conventional energy

15. Conclusion

Wind energy is playing a vital role in the world's energy markets nowadays, considering its rapid growth rate in the last few years. Some of the success stories include wind energy utilization in USA, Canada, Denmark, Germany, Turkey, Australia, China, Japan and South Korea. For these countries, the existence of wind energy policies managed to increase wind power generation significantly. In general, most countries' policies include tax exemption, the quota system, subsidies, Feed-in Tariff, involvement of research institutions, target implementation, legislation on wind energy or renewable energy law and others [2].

The wind turbine and generator technology has reached to a matured stage. The developments and improvements of the power electronic devices added an extra pace in its overall growth; however, the high penetration of wind power to the electrical network needs further consideration of the existing grid infrastructures. Grid integration issues of wind farms are the most important challenge for the future growth of this technology, which must be handled carefully.

Pakistan has set target to add a cumulative capacity of 17 GW of renewable energy by 2022 which imply a stable and sizable domestic market for potential local manufacturers with the necessary testing ground to sort out their technology and manufacturing strategies. No doubt, the task of indigenous manufacture is difficult, the challenge is great and implementation may be expensive in the early stages. However, long term benefits and rewarding. The basic living necessities (drinking water, cooking, bathing, lighting and washing) of people in Pakistan would also be met by considering renewable energy sources. Therefore, their material and cultural living conditions will be greatly improved and a balanced regional development will be attained so as to accelerate the modernization of the country as a whole.

The wind turbine constitutes the single largest cost component and this cost is lower in emerging markets, county can follow the policy of local content requirement that mandates a certain

percentage of local content for international companies investing in wind projects within the country.

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